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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

OF THE

SAN DIEGO MEETING
AT SAN DIEGO STATE COLLEGE

San Diego, California

JUNE 22–24, 1938

IN AFFILIATION WITH

THE AMERICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE

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The American Physical Society

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JUNE 6, 1938 Vol. 13, No. 3

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

SAN DIEGO MEETING, JUNE 22–24, 1938

IN AFFILIATION WITH

THE PACIFIC DIVISION OF THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE 221st regular meeting of the American Physical Society will be held at San Diego, California, on Wednesday, Thursday and Friday, June 22, 23 and 24, 1938. All sessions except that of Thursday afternoon will be held in quarters located near the Pacific Division general headquarters in Balboa Park. More specific directions may be had by applying at general headquarters. The Thursday afternoon session will be held at the Scripps Institution of Oceanography of the University of California at La Jolla, in the northern part of the city of San Diego.

Joint Session with the Astronomical Society of the Pacific. Following an established annual custom a symposium on subjects of astrophysical interest will be held. This joint session with the Astronomical Society of the Pacific will occur Wednesday afternoon, June 22, at 1:30 o'clock. Invited papers by J. R. Oppenheimer, W. A. Fowler and R. Minkowski will be presented. For topical details see page 5.

Symposium on Physical Problems of the Ocean. A symposium of six invited papers (see page 5) will be held at La Jolla on Thursday afternoon, June 23.

Regular Sessions. Sessions for the presentation of short contributed papers will be held Wednesday, Thursday and Friday forenoons, starting at 9:30 o'clock. Abstracts of these papers will be found on following pages. The session on Wednesday morning will also include a brief business meeting for consideration of the location of the next meeting and selection of a representative of this society to serve upon the Council of the Pacific Division of the American Association for the Advancement of Science.

American Association of Physics Teachers. A session of A. A. P. T., the first on the Pacific Coast, will be held Friday afternoon, June 24, at 1:30 o'clock. Invited and contributed papers upon the teaching of physics will be presented, and a special report on the A. A. P. T. manual of demonstration experiments will be heard.

Excursion to Palomar Observatory. The A. A. A. S. Committee on Excursions and Transportation have arranged a number of trips to points in and about San Diego. Of particular interest to physicists is the all-day excursion of Saturday, June 25, to Palomar Mountain and Observatory. Visitors may furnish their own motor transportation or travel in special parlor car stages leaving the Broadway entrance of the U. S. Grant Hotel at 8:00 A.M. and returning at 5:00 P.M. Stage fare, $2.50 per passenger. At Palomar Observatory a representative of the California Institute of Technology will explain the assembled equipment and its expected uses. Early registration for this excursion at A. A. A. S. headquarters is desired.

Entertainment and General Sessions. Officers and committees of A. A. A. S. in cooperation with

local institutions have arranged a variety of entertainment features, including a number of special interest to visiting ladies. Details may be had from A. A. A. S. headquarters.

Tuesday morning, June 21, at 9:00 o'clock an A. A. A. S. Divisional Symposium on "Climate and Man" will be held, and at 1:30 a series of general reviews of current research (in astronomy, oceanography, anatomy and genetics) will be presented. At 8:00 P.M., Wednesday, June 22, Dr. J. S. Plaskett, president of the Pacific Division, A. A. A. S., will deliver an address on "Modern Conceptions of the Stellar System."

Guest Accommodations. Hotel facilities in San Diego are unusually ample. A variety of accommodations located within one mile of Balboa Park may be found at rates from $2.00 per day (meals not included) upward. Many auto camps may be found within close driving distance of Balboa Park, with cabin rates starting at $1.00 per day. Meals will be served in several restaurants within Balboa Park and in a number situated just outside the West Laurel Street entrance.

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936, the Society voted that:

> No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

222. June 24–25, 1938. Toronto, Canada.
223. November 25–26, 1938. Chicago, Illinois.
224. December, 1938. Los Angeles, California.
225. December 27–29, 1938. Annual Meeting. Washington, D. C.
226. February 24–25, 1939. New York, N. Y.

PAUL KIRKPATRICK
Local Secretary for the Pacific Coast
Stanford University, California.

June 6, 1938.

PROGRAM

WEDNESDAY, JUNE 22, 9:30 A.M., BALBOA PARK

Presentation of Contributed Papers

(See accompanying abstracts)

and Business Meeting

WEDNESDAY, JUNE 22, 1:30 P.M., BALBOA PARK

Joint Meeting with the Astronomical Society of the Pacific

Symposium

Nuclear Transformations and Their Astrophysical Significance

1. **The Physical Problem of Stellar Energy.** J. R. OPPENHEIMER, *University of California and California Institute of Technology.*
2. **Nuclear Reactions as a Source of Energy.** W. A. FOWLER, *California Institute of Technology.*
3. **The Composition of Stellar Atmospheres.** R. MINKOWSKI, *Mt. Wilson Observatory.*

THURSDAY, JUNE 23, 9:30 A.M., BALBOA PARK

Presentation of Contributed Papers

(See accompanying abstracts)

THURSDAY, JUNE 23, 1:30 P.M., SCRIPPS INSTITUTION OF OCEANOGRAPHY, LA JOLLA

Symposium

Physical Problems of the Ocean

1. **Introductory Remarks.** H. U. SVERDRUP, *Scripps Institution.*
2. **Problems of Sand Movement in Coastal Regions of California.** F. P. SHEPARD, *University of Illinois,* AND U. S. GRANT, *University of California at Los Angeles.*
3. **Problems Relating to the Distribution of Sedimentary Materials in the Sea.** ROGER REVELLE, *Scripps Institution.*
4. **The Behavior of Small Particles in Sea Water, with Special Reference to Floating or Sinking.** W. E. ALLEN, *Scripps Institution.*
5. **Problems Suggested by Turbulence.**
   a. **Practical Methods of Investigation.** H. U. SVERDRUP, *Scripps Institution.*
   b. **Attempts to Measure Turbulent Motion.** G. F. MCEWEN, *Scripps Institution.*
6. **Thermodynamical Theory of Temperature Gradients in the Sea at Great Depths.** R. D. GORDON, *Scripps Institution.*

FRIDAY, JUNE 24, 9:30 A.M., BALBOA PARK

Presentation of Contributed Papers

(See accompanying abstracts)

ABSTRACTS OF CONTRIBUTED PAPERS

WEDNESDAY MORNING

1. Collimated, Variable Energy Beam of Pure Thermal Neutrons. LUIS W. ALVAREZ, *Radiation Laboratory, University of California.*—The cyclotron beam has been modulated at 120 cycles per second, giving almost square pulses of neutrons lasting about 0.004 second each. The sensitivity of a linear amplifier has been modulated at the same frequency, but with opposite phase, so that no fast neutrons are recorded. If a Li lined chamber is placed 8 meters from the source, thermal neutrons will just reach it in 0.004 sec., and therefore be registered. With Cd sheets on sides and back of the chamber, and Cd diaphragms in front, no neutrons but thermal ones directly from the source can be counted, giving a collimated beam. (No other neutrons can live long enough in the free state.) This fact has been confirmed experimentally. If the chamber is moved toward the source, the effective temperature of the recorded neutrons drops with the square of the distance, while their number remains constant (until the breakdown of the Maxwellian distribution, the $1/v$ detection law, or the inverse square law sets in). With a BF_3 chamber, the number of slow neutrons is too great for the collecting voltage at present available. Descriptions of the modulating circuits will be given together with reports of preliminary absorption and scattering experiments.

2. Excited State of He^3. L. I. SCHIFF,* *California Institute of Technology.*—Bonner's recent experiments indicate the existence of a bound excited state of He^3 about 2 Mev above the ground state. Since this is probably a P state, it involves interactions that are not determined by the normal state energies of the light nuclei or by existing data on scattering. The variational method with a two-parameter wave function yields no bound excited state when the usual saturating forces are used. Since this method with a similar wave function gives 0.71 of the ground state energy of He^3, and since the excited state is well bound (3.5 Mev below the continuum of a deuteron plus a proton), one would expect the variational method to yield fairly accurate results. In order to obtain a state in roughly the indicated place with two-body non-spin orbit interactions, it is necessary to use strongly non-saturating forces between both like and unlike particles; these forces just avoid binding the ^1P and ^3P deuteron and ^3P di-neutron and di-proton. Such interactions would probably cause serious difficulties with the systematics of nuclei.

* National Research Fellow.

3. The Electrical Axis of the Heart by Direct Observation. W. H. JORDAN, *University of South Dakota.*—The usual method of finding the direction of the heart axis is to analyze the electrocardiograms taken with three successive connections to the body. Now a circuit has been developed whereby the direction of the heart axis can be seen directly by observing the trace of the electron beam on a standard cathode-ray tube. The customary three leads to the right arm, left arm, and left leg are employed. The bioelectrical potentials developed are amplified by three amplifiers star connected. The amplified voltage can be connected to a special triple axis cathode-ray tube as shown by Hollman[1] or to the usual type of cathode-ray tube containing only horizontal and vertical deflecting plates. The connections necessary to maintain proper magnitude and phase relationships in the latter case are described.

[1] Hollman, Electronics, Jan. (1938).

4. Vitrification and Crystallization of Living Cells at Low Temperature. ALEXANDER GOETZ AND S. SCOTT GOETZ, *California Institute of Technology.*—The conditions which determine whether a liquid when cooled far below its melting point will enter the crystalline or the vitreous state are studied on live organic cells (Saccharomyces Cerevisiae). Substantial evidence has been found that the capacity for life ceases with crystallization of the cell plasma and that it is preserved when the physical conditions of cooling favor vitrification. The cooling rate (dT/dt) was varied from $10°$–10^4 deg. sec.$^{-1}$ down to final temperatures (T_0) of $-185°$C and $-252°$C. It was found that for the same T_0 the cooling rate controls the death rate (δ) almost completely, as δ is larger than 75 percent when crystallization is favored, whereas it can be decreased down to 3 percent under vitrifying conditions. The duration of exposure (τ) does not affect δ at -185 C if τ is varied by 10^3. The temperature T_0 below $-185°$C does not affect δ, although a considerable influence of τ was found at $-50°$C. Repeated exposures of the same cells under conditions not especially favoring vitrification were studied and the integral death rate (δ_n) after the nth exposure was checked against the expectancy for an invariance of δ with n. It appears that $\delta(n)$ is not controlled by simple probability relations and that factors of biological nature enter.

5. Constitution of the Solfataric Gases at Kilauea Volcano, Hawaii. STANLEY S. BALLARD, *University of Hawaii.*—A preliminary analysis of the gases emanating at the Sulfur Bank near Kilauea Volcano has been completed. The purpose was to establish the identity of all constituents other than the obvious steam and sulfur vapor. Chief collections were made in September, 1936, and August, 1937. A combination of chemical and spectroscopic methods of analysis was used. The chief constituent (other than steam) proved to be sulfur dioxide, which constituted as much as 90 percent of some samples. Carbon dioxide was present in amounts equal to about one-twelfth the sulfur dioxide content. Oxygen and nitrogen were present always approximately in the normal atmos-

pheric ratio, but in absolute amounts which varied widely from sample to sample. Argon was present in the nitrogen residues, but no other rare gases were detected. No significant trace of the combustible gases ordinarily associated with volcanism was detected in any sample. In general these results do not seem to be incompatible with the partial analyses of Allen[1] made in 1922, although it may be that the sulfur dioxide content has increased since that time. Acknowledgment is made of the collaboration of Professor John H. Payne in the chemical aspects of the analysis.

[1] E. T. Allen, Bull. Hawaiian Volcano Observatory **10**, 89 (1922).

6. Alterations in the Near Infra-Red Absorption Spectra of Water and of Protein Molecules when Water is Bound to Gelatin. JOSEPH W. ELLIS AND JEAN BATH, *University of California at Los Angeles.*—The absorption spectrum of a 0.20 mm oven-dried gelatin specimen consists entirely of two CH bands (1.72 and 2.28 μ) and three NH bands (1.50, 2.05 and 2.18 μ) in the 1–2.5 μ region. A similar specimen, having absorbed from a saturated atmosphere water equal to 35 percent of the total weight, shows the CH bands unaltered but the NH bands diminished in intensity. Another specimen similarly swollen with 99.9 percent D_2O shows the NH bands more nearly obliterated. In the $(\nu_\sigma+\nu_\pi)$ band of light and heavy water (1.44 and 1.99 μ, respectively) and in the $(\nu_\sigma+\nu_\delta)$ band of light water (1.91 μ), portions of both the high and low frequency sides are missing, indicating the absence or diminution in number of both vapor-like and the most highly perturbed water molecules. The $(\nu_\sigma+\nu_\delta+\nu_R)$ band of light water at 1.79 μ (ν_R = hindered rotation frequency) is sharpened in the swollen gelatin spectrum. An analogous band $(\nu_\sigma+\nu_\pi+\nu_R)$ at 1.35 μ appears for the first time. All the alterations cited in the water and protein bands indicate, or are consistent with the hypothesis, that the water molecules taken on by the gelatin from a saturated atmosphere are bound to NH or NH_2 groups by means of hydrogen bridges.

7. α-Particles from the Disintegration of Lithium by Deuterons. H. STAUB* AND W. E. STEPHENS, *W. K. Kellogg Radiation Laboratory, California Institute of Technology.*—Using an ionization chamber and linear amplifier with high differentiality the number-range curve of α-particles arising from disintegration of Li by deuterons was taken at 800 kv peak. The continuous distribution due to the reaction:

$$Li^7+D^2\rightarrow n^1+Be^8;\ Be^8\rightarrow 2He^4 \qquad (1)$$

was observed, ranging up to about 7.7 cm. On it was superimposed a homogeneous group agreeing in its 7.6 cm mean range, within the limits of error and when corrected to the same voltage, with one observed by Williams, Shepherd and Haxby[1] and ascribed by them to the reaction

$$Li^7+D^2\rightarrow He^4+He^5. \qquad (2)$$

This leaves the He^5 unstable by 0.8 Mev. In our experiment the peak at 7.6 cm is, as in reference (1), somewhat wider than the peak observed at 13.0 cm, due to the reaction

$$Li^6+D^2\rightarrow 2He^4, \qquad (3)$$

which has a width of about 0.9 cm at half-maximum. An estimate based on the theory of Bethe and Livingston[2] shows that this width is entirely due to the deep penetration of the deuterons at the high bombarding voltage of 0.8 Mev. The numbers of disintegrations at 0.8 Mev for the three processes are found to be in the ratio 50 : 10 : 1 for (1), (2) and (3) respectively. Similar ranges and intensity ratios were obtained when the counter was biased low to give the integral number-range curve.

* International Exchange Fellow.
[1] Williams, Shepherd and Haxby, Phys. Rev. **51**, 888 (1937); **52**, 390 (1937).
[2] Bethe and Livingston, Rev. Mod. Phys. **9**, 286 (1937).

8. Neutrons from the Break-Up of He^5. W. E. STEPHENS AND H. STAUB,* *W. K. Kellogg Laboratory, California Institute of Technology.*—We have reinvestigated[1] the energy spectrum of the neutrons from the disintegration of lithium by 0.8 Mev (a.c.) deuterons in the region from 2 Mev to 6 Mev. A sharp drop in the number of neutrons at 3.8 Mev is interpreted as the high energy limit of the continuum of neutrons from the two stage reaction

$$Li^7+D^2\rightarrow He^5+He^4+Q_1 \qquad (1)$$

$$He^5\rightarrow He^4+n^1+Q_2. \qquad (2)$$

Williams, Shepherd and Haxby[2] have established the existence of reaction (1) and have determined the value of Q_1 to be 14.3 Mev. Using this value and the known masses, the value of Q_2 is calculated to be 0.8 Mev. For a bombarding energy of 0.8 Mev for the deuterons, the neutron continuum can be calculated to extend from 0.1 Mev to 3.8 Mev. Since this continuum is superimposed on the neutrons from the reaction

$$Li^7+D^2\rightarrow Be^8+n^1+Q_3 \qquad (3)$$

and probably some from Li^6, all that can be observed with certainty is the high energy cut off. From the value of 1 to 5[3] for the relative yield of reaction (1) to reaction (3) at our bombarding voltage, we can estimate that reaction (2) accounts for most of the neutrons giving the sudden rise. It may be, however, that some of them are due to the reaction

$$Li^6+D^2\rightarrow Be^7+n^1+Q_4 \qquad (4)$$

as suggested by Roberts and Heydenburg.[4]

* International Exchange Fellow.
[1] Bonner and Brubaker, Phys. Rev. **48**, 742 (1935).
[2] Williams, Shepherd and Haxby, Phys. Rev. **52**, 390 (1937).
[3] See preceding abstract.
[4] Abstract 78, Washington meeting (1938).

9. Radiative Losses by Particles of Anomalous Magnetic Moment. SAMUEL B. BATDORF AND ERICH W. BETH, *University of California.*—The fact that the absorption of the penetrating constituent of cosmic radiation is intermediate between expected values for electrons and for protons is generally explained by the assumption of an intermediate mass. While it is difficult to draw conclusions

concerning this mass from Dirac type equations containing the magnetic moment as an arbitrary parameter the possibility nevertheless exists that a suitable choice of magnetic moment might render the particle highly penetrating. The radiative losses were accordingly calculated by the von Weizsäcker method, the bremsstrahlung being first treated in the reference system in which the cosmic-ray particle is originally at rest and the results then transferred by a Lorentz transformation to the coordinate system at rest with respect to the nucleus. We find that, while we can choose the magnetic moment so that the radiative losses increase by any desired amount, they can be decreased by only a very small fraction by choice of the magnetic moment. We conclude that a particle of this type must have a mass much larger than the electron mass in order to account for the penetrating constituent of cosmic radiation.

10. Mass of Cosmic-Ray Particles. R. M. LANGER, *California Institute of Technology.*—A wide range of heavy electron masses in the cosmic radiation would lead in a particular cloud chamber to a distribution of measurable values of mass in a restricted region according to the upper limit of $H\rho$ measurable in the apparatus. For a limiting $H\rho$ equal to 10^5 the favored mass is about 10^2 electron masses. For smaller $H\rho$ neither the heavy nor the light electrons will be very penetrating. This can be shown easily with the help of curves connecting energy, energy loss, mass and $H\rho$. Moreover chambers with higher limiting $H\rho$ will get measurable tracks much faster than those with lower limits and heavy tracks due to lighter masses will remain relatively rare. For lighter masses other forms of detection are advantageous. The lighter electrons may appear in showers and account for the narrow pencils of straight tracks sometimes observed. The second maximum in shower frequency at about 20 cm of lead is just what would be expected if most of the electrons producing the showers had a mass of about 3 electron masses. A particularly interesting estimate of mass can be made from data published by Ehrenfest[1] who mentions a particle whose change in $H\rho$ indicates a mass of about 7 electron masses.

[1] P. Ehrenfest, Jr., Comptes rendus **206**, 428 (1938).

11. Measurements of the Mobility of Potassium Ions at High Field Intensity and Low Pressure. ALLEN V. HERSHEY, *University of California (Introduced by Leonard B. Loeb).*—The mobility of potassium ions at high field intensity and low pressure has been measured by the Townsend deflection method in the gases H_2, He, N_2, and A. The product of mobility and pressure should be a function of the ratio of field intensity to pressure. Thus, at a given value of E/p (E=field intensity in volts per cm; p=pressure in mm Hg), the product Kp (K=mobility in cm per sec. per volt per cm) should be the same at all pressures. This was found to be true at the highest pressures investigated but not at the lowest, apparently because of a breakdown in the method, rather than a true variation in mobility. At a small value of E/p, the results agreed to within a few percent with the measurement by Tyndall and Powell[1] and by Powell and Brata.[2] As E/p is increased, the mobility at first rises, passes through a peak, and then diminishes. The initial rise in nitrogen has been reported by Mitchell and Ridler.[3] Pronounced peaks were obtained in H_2, N_2, and A, but not in He.

[1] Tyndall and Powell, Proc. Roy. Soc. **136A**, 145 (1932).
[2] Powell and Brata, Proc. Roy. Soc. **138A**, 117 (1932).
[3] Mitchell and Ridler, Proc. Roy. Soc. **146A**, 911 (1934).

THURSDAY MORNING

12. Resonance Broadening of Spectral Lines. W. V. HOUSTON, *California Institute of Technology.*—The radiationless transfer of excitation energy from one atom to another during a collision is one cause of the broadening of spectral lines. It can be shown that the broadening produced in this way is the same for all members of a multiplet, in agreement with the observations, but considerably less in magnitude than that observed. Another source of broadening can be found in the coupling between the motion of the whole atom and the electronic motion. This also is the same for all members of a multiplet, and broadens a line to about the same extent as the first cause.

13. Absorption of Sound in Carbon Dioxide and in Carbon Disulphide. V. O. KNUDSEN AND E. FRICKE, *University of California at Los Angeles.*—Sound absorption measurements in pure CO_2 at atmospheric pressure and 22°C have been conducted which, together with measurements by Curtis, confirm the collision theory of anomalous absorption as developed by Einstein, Kneser, and others. The absorption coefficient is appreciable at frequencies as low as 2000 cycles, and increases to a maximum of 0.317 per wave-length at 77,000 cycles. This maximum is higher than values obtained by previous workers, and indicates that both the deformation and symmetrical valence vibrations participate in the exchanges between translational and vibrational energy. Small impurities, as water or alcohol vapors, affect the absorption greatly; the entire absorption band is shifted to higher frequencies. Measurements in mixtures of CO_2 in O_2 and CO_2 in N_2 indicate that neither the O_2 nor N_2 is appreciably excited by collisions with CO_2. Measurements in CS_2 reveal an absorption similar to that for CO_2 except that the absorption begins at about 10,000 cycles. In mixtures of CS_2 and O_2, the observed absorption at frequencies below 10,000 cycles is accounted for by assuming that only the vibration of O_2 molecules is excited by collisions with CS_2 molecules; at higher frequencies the CS_2 molecules also are excited, principally by collisions with other CS_2 molecules.

14. A Probe Investigation of Anode Spots. J. E. HENDERSON AND S. M. RUBENS, *University of Washington.*—Anode

spots are readily produced in a glow discharge maintained in the chamber formed between two concentric copper spheres of diameters 53.4 and 5.08 cm, the inner sphere being anode. These spots are striking in appearance, especially since they arrange themselves in symmetrical patterns over the surface of the anode. Pressure, current density, and surface conditions of the anode determine the number and size of the spots in agreement with earlier work.* Similar conditions prevail when the inner sphere is replaced by a thin disk, the spots first appearing near the edge where the field is greatest. Space potentials, electron concentrations, and electron temperatures measured in the plasma surrounding the spots with a cylindrical Langmuir probe indicate that the spots are sheaths possessing a negative space charge. This accounts for the symmetrical arrangements observed. A spot having the same properties as the others could be formed at will on a small insulated disk mounted flush with the anode surface if the potential of the disk was raised to a suitable potential above the anode depending on the gas, pressure, and current density.

* C. H. Thomas and O. S. Duffendack, Phys. Rev. **35**, 72 (1930).

15. Spherical Ground Joints for Vacuum Systems. S. M. Rubens and J. E. Henderson, *University of Washington.*—The problem of providing for a universal type of motion of a probe employed in some glow discharge investigations was solved by using a ground glass joint of which the surfaces in contact were sections of spheres. Such surfaces are readily formed by blowing the glass into simple molds. The grinding is easily accomplished by rotating and rocking the convex surface within the concave one with a random motion. The closeness of contact between the surfaces is far superior to that of the ordinary conical ground joint. Joints of this type exhibit unusual flexibility and seem to have numerous applications besides the one indicated. A five way stopcock has been constructed on this principle. Samples of these devices will be exhibited.

16. The Probable Ionization of High Speed Electrons in Nitrogen. Robert B. Brode and Dale R. Corson, *University of California.*—The ionization due to high speed electrons has been measured by counting the drops in the cloud chamber tracks. By delaying the expansion about $\frac{1}{2}$ second after the passage of the ionizing particle the tracks were broadened by diffusion so that counting was easy and reliable. The energy of the particle was obtained from the deflection of the track in a magnetic field. Tracks from 10 to 30 cm in length were counted in fields from 800 to 2500 gauss. The ionization as determined by these drop counts decreased rapidly from about 100 drops per cm in 1 atmosphere of nitrogen at an energy of 10^5 ev to a minimum of 50 drops per cm at 2×10^6 ev. With increasing energy the ionization increased to about 70 drops per cm at 10^8 ev. These measurements are in good agreement with the theoretical prediction for the variation of ionization with energy for electrons in this energy range.

17. The Beilby Layer on Thin Ground Quartz Crystals. F. R. Hirsh, Jr., *California Institute of Technology.*—A ground quartz crystal with the two sides of unequal roughness was found to give spuriously double spectral lines, the stronger component of which came from the rougher side, i.e. the reflection here is apparently a surface phenomenon alone due to a disturbed (Beilby) layer of a crystalline nature. With light etching by use of H_2F_2 these surface reflections weaken and reflection starts from the Bragg planes in the crystal body; this is evidenced by the filling in of the space between the spurious double components with reflected x-ray energy. If the crystal is etched heavily (42 hours in 50 percent H_2F_2) the two spurious spectral line components disappear, leaving between their former positions a single line of true Laue reflection origin. This result supports the idea that the ground crystal is covered by a crystalline Beilby layer of atoms aligned by the external fields of the crystal itself. If the curved crystal distorted elastically throughout its entire radial thickness, the two surface layer reflections would merge due to exact focussing. That it does not occur, is evidence that the surface (Beilby) layer differs in physical nature from the crystal body.

18. Evidence for Surface Layers in Cleaved Calcite Crystals. V. L. Bollman and Jesse W. M. DuMond, *Occidental College and California Institute of Technology.*—In a continuation of earlier work[1] radiation from a molybdenum target x-ray tube was passed through a slit of a precision transmission spectrometer and then through a thin cleaved calcite crystal. The spectral lines obtained on a photographic film were found to be double and to exhibit marked fluctuations in intensity along the lines. From the geometry of the arrangement it was concluded that the radiation producing the double lines came from the entrance and exit surfaces of the calcite crystal. Other tests led to the conclusion that the intensity fluctuations along the lines were produced by disturbances on the surfaces of the crystal. Recently another series of tests has been made with the same apparatus. A cleaved crystal exhibiting the properties mentioned above was etched one face at a time and exposures taken to ascertain the nature of the reflections. Mild etching with 0.7 *N* HCl according to a technique worked out by Manning[2] failed to affect the nature of the photographic pattern. Prolonged etching, however, removed the sharp line reflections, coming from the surfaces. A less well-defined fainter line then appeared in a position between the "surface" lines. This latter trace showed no sign of intensity fluctuation along the length of the line.

[1] DuMond and Bollman, Phys. Rev. **50**, 97 (1936).
[2] K. V. Manning, Rev. Sci. Inst. **5**, 316 (1934).

19. Photoelectric Long Wave-Length Limit of Magnetized Iron. Donald H. Loughridge and N. Kermit Olsen, *University of Washington.*—The photoelectric current from a cylindrically shaped piece of iron is measured with a FP-54 bridge circuit when the iron is subjected to field strengths from zero to 5000 gauss. These readings are taken for different wave-lengths and plotted on Fowler curves to obtain the threshold frequency of the iron. Acceleration potentials always in excess of that required for saturation are used on the photo-cell. The effect is most

pronounced near the long wave-length limit of the iron, and the change in the threshold frequency of the iron due to the magnetic field is derived from proper treatment of the Fowler curves. The effect is of the order of a few angstroms for the data taken up to date. Alternate readings of photoelectric current, with magnetic field on and off, are taken to minimize the effect of such unavoidable sources of fluctuation as arc intensity, electrometer tube adjustments, and temperature changes. The threshold frequency of the iron is about 2600 angstroms, which checks the value given by Cardwell.

20. Spark Breakdown Potentials in A, N_2 and H_2 for Pt and Na Cathodes. FLORENCE EHRENKRANZ, *University of California (Introduced by Leonard B. Loeb).*—Curves were obtained for sparking potentials between fixed plane parallel electrodes in pure mercury-free argon, nitrogen and hydrogen for Pt and Na cathodes as a function of the pressure times the plate separation. The effect of heated Pt and Na cathodes on the sparking potentials in hydrogen was investigated. The presence of Na lowers the sparking potentials near the minimum by 50 percent, 28 percent, and 30 percent in A, N_2 and H_2, respectively. The percentage lowering is 7.5 for $p\delta$ equal to 240 mm×cm in A, 20 for $p\delta$ equal to 360 in N_2, and 11 for $p\delta$ equal to 320 in H_2. Predischarge currents with Pt cathodes were less than 10 amp.; with Na cathodes, currents of 360 microamperes at $p\delta$ equal to 356 in N_2 and of 8 microamperes at $p\delta$ equal to 320 in H_2 occurred. Sparking potentials in H_2 with heated Pt and Na cathodes are identical within the limits of experimental accuracy. The probable explanation of this result is that the formation of NaH removes all of the Na and destroys the volatile substance which causes the lowering in the cold Na experiments.

21. Angular Distributions of Recoil and Photoelectrons Produced by 300 to 800 kv X-Rays in Nitrogen. HAROLD TRUEBLOOD AND DONALD H. LOUGHRIDGE, *University of Washington.*—By the use of an automatically controlled cloud chamber, and the 800,000-volt x-ray tube of the Swedish Hospital, Seattle, a large number of photographs have been made of the effects of high voltage x-rays passing through nitrogen. A magnetic field of about 400 gauss enabled the energies to be measured. Recoils were distinguished from photoelectrons by the criterion of the maximum energy allowable from Compton's formula as a function of the angle. Curves plotted with total electrons, at a given ejection angle, against energy show a definite break at the calculated value of the Compton energy. The experimental angular distribution curves for the recoils fit well with the Klein-Nishina distribution. The gradual shift in the most probable angle of ejection for photoelectrons, as a function of the energy, checks well with the Sommerfeld calculations in this region.

22. Long Period Radioactive Zinc. J. J. LIVINGOOD AND G. T. SEABORG, *Radiation Laboratory, University of California.*—A chemically identified radioactive zinc isotope, produced by irradiating zinc with 8 Mev deuterons, has been found to have a half-life of 7 months. Positrons are emitted, which definitely identifies the activity with Zn^{65}. Electrons are also observed, as well as an anomalously high ratio of gamma-rays to particles; this indicates K electron capture as an alternative method of decay. An activity with this period and similar characteristics of radiation has recently been reported[1] after proton bombardment of copper; this is consistent with the above isotopic identification.

[1] S. W. Barnes and George Valley, Bull. Am. Phys. Soc. **13**, No. 2, 40 (1938).

23. Normal Modes of Vibration of a Body-Centered Cubic Lattice. PAUL FINE, *California Institute of Technology.*—The frequencies of the normal vibrations of a body-centered cubic lattice have been calculated for atomic constants obtained from the elastic constants of tungsten. The results suggest an approximation to the frequency distribution which takes into account the atomic nature of the crystal. The vibrations are found to fall into three groups, each having the same kind of distribution, which is characterized by a frequency of maximum probability computed from the elastic constants. From these frequency distributions the specific heat due to the atomic vibrations is calculated. The model used, in which elastic forces between atoms are assumed, leads to the Cauchy relations between the macroscopic elastic constants, and these are satisfied only approximately for tungsten and not at all for many other substances. According to Fuchs,[1] the failure of the Cauchy relation for monovalent metals is due solely to the influence of the electrons on the compressibility of the crystal. If then the compressibility is determined from the other elastic constants by means of the Cauchy relation and this value is used in calculating the characteristic frequencies, the specific heat obtained differs from that observed by an amount which may be attributed to the electronic contribution.

[1] K. Fuchs, Proc. Roy. Soc. **A153**, 635 (1936).

24. Magnitude of Accelerated Current in the Cyclotron. ROBERT R. WILSON, *Radiation Laboratory, University of California.*—The magnitude and distribution of the ion currents accelerated in the Berkeley cyclotron have been measured by means of a water-cooled probe introduced between the accelerating electrodes or dees and noting the heating of the water. As the probe is moved inward, this current is found to increase linearly from zero at the outside edge of the dee to a large value of about one-half of a milliampere of deuterons when the probe is in about one-sixth of the distance into the center. At this position apparently all the beam is being intercepted, and moving in farther does not give an appreciable increase of current. Measurements on the initial ionization at the center indicate that approximately all the available ions are being accelerated. Under more favorable running conditions, it is expected that there is easily as much as one milliampere of six to nine million volt deuterons circulating within the dees. Of this only ten percent is withdrawn by the deflector; henceforth the large circulating current will be used, especially for long bombardments, by introducing targets directly into the circulating beam at various positions which will not seriously interfere with the deflected beam.

FRIDAY MORNING

25. The Objective Quantitative Definition of the Graininess of Photographic Emulsions. A. DEMBER, A. GOETZ AND W. O. GOULD, *California Institute of Technology.*—Methods to determine the graininess of photographic emulsions objectively have only been developed recently and consist so far in measuring the average transparency fluctuation. The method analyzed here bases on the evaluation of a microphotometric record representing the relative transparency fluctuations ($\Delta T/T_m$) of a uniformly exposed area of the emulsion. Besides the sum of the fluctuations, the distribution of the areas, they occupy as a function of their magnitude, can be determined. The graininess (G) is defined from the distribution (probability) function $\pi = C/G \cdot \exp -[\Delta T/(T_m G)]^n$; it indicates the inverse rate of decline of the occurrence of relative transparency fluctuations with the deviation from the average transparency (T_m). For evaluating the microphotometric records an analyzer is used, allowing the direct reading of the probability integral function. Thus the numerical value of G is obtained; furthermore the distribution law, determined by the exponent n, is checked with each measurement; accidental disturbances in the emulsion can thus be eliminated. The value of n is found $\leqq 2$; therefore a Gaussian (statistical) distribution gives a close representation. The numerical value of G depends on the scanning area (α) of the microphotometer, so for obtaining comparable values this area has to be kept constant. Otherwise a correction according to the function $G(\alpha)$ has to be applied.

26. An Instrument for the Objective and Quantitative Determination of Photographic Graininess. W. O. GOULD, A. GOETZ AND A. DEMBER, *California Institute of Technology.*—The instrument consists of a microphotometric recorder and a photoelectric integrator. In the former unit the relative transparency fluctuations ($\Delta T/T_m$) of a uniformly exposed section of an emulsion are recorded under high resolving power and magnification by means of a photo-cell, the amplified output of which is traced with a high frequency galvanometer on 35 mm film. The motion of the latter is coordinated with that of the emulsion. A variable area record is thus produced which represents truly $\Delta T/T_m$ of the emulsion area scanned (0.2 mm²). This record is analyzed by the integrator as follows: It is placed on a revolving drum and scanned by an illuminated slit. The light transmitted falls upon a photo-cell. Its current is thus proportional to the average occurrence of $\Delta T/T_m$ for a value of transparency determined by the lateral position of the slit on the record. As the slit is moved slowly across the record the shape of the transparency distribution function is obtained. The current is measured with a scale consisting of a family of distribution curves plotted in polar coordinates for different graininess parameters. The scale is rotated synchronously with the slit motion. The indicating light beam selects and follows a particular distribution curve as the slit is moved, thus evaluating numerically the graininess.

27. A Search for an Electrostatic Analog to the Red Shift. H. T. DRILL, *University of Washington (Introduced by J. E. Henderson).*—The existence of a gravitational red shift suggests the possibility of a like dependence of frequency upon electrostatic potential. A search for such an effect was carried out by Kennedy and Thorndike[1] in 1931. The frequency shifts quoted by them, although within their quoted probable error, were very close to their probable error, suggesting the possibility that further refinements might yield positive results. As the interferometer used by them was available and not easily improved, an increase in sensitivity was most readily obtained by increasing the potential difference between the light source and interferometer. This was accomplished by mounting the mercury arc used as a source within the sphere of a Van de Graaf generator. The generator was operated at 300 kilovolts, both positive and negative with respect to the interferometer. This is approximately six times the potential difference used by Kennedy and Thorndike. The frequency changes observed were well within the probable error for the light source at both positive and negative potentials, indicating a frequency change of less than one part in 10^{15} per volt. This is clearly a null result.

[1] R. J. Kennedy and E. M. Thorndike, Nat. Acad. Sci. **17**, 620–622.

28. The Separation of Radioactive Substances Without Use of a Carrier. D. C. GRAHAME AND G. T. SEABORG, *University of California.*—Carefully purified gallium-free zinc was bombarded with 8 Mev deuterons in the Berkeley cyclotron to form radioactive gallium. It was found possible to extract radioactive gallium chloride with pure ether from an aqueous solution[1] (6N in HCl) without the addition of inactive gallium chloride as a carrier. The partition coefficients between the liquid phases for the chlorides of Ga^{68} (1 hr.)[2] and Ga^{67} (83 hr.)[3] were found to be identical with those observed for gallium chloride in ordinary amounts. Long lived radioactive cobalt isotopes are formed by the bombardment of iron with 6 Mev deuterons.[4] The minute amounts of cobalt thus formed were found to be distributed between liquid phases in the same manner as cobalt in larger amounts. The distribution of minute quantities of cobalt chloride between water and ether was not changed by the presence of relatively large amounts of inactive ferric chloride. The use of extraction methods offers a simple means of separating completely and in the most concentrated form the radioactive isotopes of many elements.

[1] Noyes and Bray, *Qualitative Analysis for the Rare Elements* (Macmillan Co., 1927), p. 151.
[2] Livingood, Phys. Rev. **50**, 425 (1936).
[3] Alvarez, Phys. Rev. **53**, 606 (1938).
[4] Livingood, Seaborg and Fairbrother, Phys. Rev. **52**, 135 (1937).

29. On the Viscosity of Nonpolar Liquids. S. KYROPOULOS, *California Institute of Technology (Introduced by A. Goetz).*—The phenomenon of viscosity drop by flow orientation (mechanical orientation in a Couette apparatus) with nonpolar, extremely dissymmetrical molecules, points to a marked influence of the dissymmetry of polarizability

on this phenomenon and on viscosity in general. In such liquids the forces of interaction are practically confined to the dispersion forces and there are very definite states of minimum mutual potential energy. This results in the temporary formation of complexes of higher saturation of those residual fields of force which interact in the phenomenon of viscosity. An analogous case is represented by long chain hydrocarbon molecules with polar head, where dipole forces are eliminated to a great extent, insofar as viscosity is concerned, by association, resulting in a viscosity behavior similar to corresponding paraffins. With small molecules, even small permanent moments tend to suppress the influence of the optical anisotropy, resulting in a type of complexes which is ultimately, even temporarily, strongly determined by the dipole forces.

30. A Search for Temperature Changes Accompanying Field Emission at High Temperatures. G. FLEMING AND J. E. HENDERSON, *University of Washington*.—In work previously reported[1] a search was made for temperature changes of a field emitter at room temperature; no temperature change of as much as 1°C was observed. Using similar apparatus this same type of investigation has been extended up to the thermionic region. Gold and platinum thermocouples fashioned into points (one sharp and one dull) were placed in opposition and used as emitters up to the melting point of gold. Similar measurements were made to approximately 1600°K using tungsten-platinum thermocouples. Heating was accomplished by 500-cycle currents from which the d.c. instruments were protected by high inductances. Total field currents as large as three milliamperes were used. Even up to temperatures at which a minute thermionic emission occurred, there was found no temperature change of more than 2°C, the estimated uncertainty in the measurements. The result indicates that below the temperature at which thermionic emission sets in strongly only a small portion of the total number of electrons emitted partake of the thermal energy of the metals studied.

[1] J. E. Henderson and G. M. Fleming, Phys. Rev. **48**, 486 (1935).

31. The First and Second Townsend Ionization Coefficients for Pure H_2. DONALD H. HALE, *University of California* (*Introduced by Leonard B. Loeb*).—Experiments were made to determine the Townsend coefficients for ionization by collision in pure H_2. Precautions were taken to exclude Hg vapor from the ionization chamber. The experiments were carried out using the method developed by Bowls.[1] The values of α/p plotted as $f(X/p)$ show wide variations from a similar curve plotted from the values of Townsend and Hurst[2] for experiments carried out in H_2 which was contaminated with Hg. The values of α/p for the Hg free H_2 are lower by as much as thirty percent for values of X/p below 300. The curve of β/p plotted as a $f(X/p)$ shows a well-defined peak at an X/p of 100. It then decreases reaching a minimum at an X/p of 200 and shows a gradual increase at the higher values of X/p. The curve of values of γ $(=\beta/\alpha)$ plotted as $f(X/p)$ shows a similar peak at an X/p of 100. These peaks are much like those found by Bowls[1] for pure N_2. However, in H_2 they occur at slightly lower values of X/p and are less pronounced.

[1] Bowls, Phys. Rev. **53**, 293 (1938).
[2] Townsend and Hurst, Phil. Mag. **8**, 738 (1904).

32. Motion Picture Polarigraph for Sky Light Investigations. WILLI M. COHN, *Berkeley, California*.—An instrument has been developed for replacing visual measurements of polarization, transmission, etc., by permanent records. A modified Martens polarization photometer is connected with a motion picture camera. The Nicol prism rotates, and the photometric field is photographed every ten degrees. The position of the Nicol prism is indicated on each record. The intersection of the density curves for the two halves of the photometric field is determined. A set-up is presented for the rapid determination of the polarization of the entire vault of the sky. It is outlined that the polarization of sky light seems to be a very sensitive supplement to routine measurements of radiation from sun and sky and of the turbidity of synoptic air masses. It seems desirable to find out if, for instance, the approach of typhoons may be predicted from polarization measurements, since changes in the polarization of sky light seem to occur a long time before any clouds, etc., appear. Further applications of the instrument are obvious for polarimetric work in the laboratory and in the plant, whenever visual determinations should be replaced by permanent records, for instance in connection with sugar analysis, biological, and medical work, etc.

33. Where Does the Light of the Night Sky Originate? JOSEPH KAPLAN, *University of California at Los Angeles*.—It is generally agreed that the light of the night sky originates higher in the atmosphere than do most auroral displays. Cabannes and Dufay, by an experimental procedure of not great accuracy, place this level between 200 km and 300 km. The writer has produced afterglows in very weakly excited nitrogen, at low pressures, which agree with the light of the night sky and give evidence of its high origin. Recent experiments on afterglows in nitrogen at pressures around 30 mm indicate an origin of some of this light as low as the lowest auroral displays. In fact, the best laboratory reproduction of a night sky spectrum has been produced in these high pressure glows. Such features as the Vegard-Kaplan bands, first positive bands originating on very high vibrational levels, second positive bands, cyanogen tail bands, the new 3471 line of nitrogen, and absence of the first negative bands, are prominent in these afterglows. These are all definite or highly probable characteristics of the light of the night sky. Although the two red lines of oxygen probably originate at higher levels, it seems reasonable to suggest that most of the radiation originates in the lower regions of the upper atmosphere.

34. On Neutron Stars. F. ZWICKY, *California Institute of Technology*.—(a) Collapsed neutron stars,[1,2] according to present knowledge, represent *states* of *lowest energy* that matter may assume without being completely transformed into radiation. (b) The transformation of stellar matter into the neutron state may occasionally proceed very rapidly. The stupendous rate at which energy was

liberated in some of the recently observed super-novae may thus find an explanation. (c) The relative change of wave-length due to the gravitational redshift of light originating on the surface of neutron stars tends in limiting cases toward unity. Such redshifts may be observable in super-novae and in their remains. (d) According to the general theory of relativity the mass of a star of given density cannot surpass a certain critical value (Schwarzschild limit). At this limit the energy liberated because of gravitational packing is $(1-4/3\pi)Mc^2=0.58Mc^2$, where M is the *proper mass* of the star. The derivation of this result which was obtained in discussion with Professor R. C. Tolman will be communicated elsewhere. For neutron stars the *limiting* proper mass is approximately $M_L=R^{3/2}m_N=1.8\times10^{35}$ grams, where $R=e^2/\Gamma m_p m_e=2.29\times10^{39}$ is the ratio of the electrical to the gravitational attraction between a proton and an electron and m_N is the mass of a neutron.

[1] W. Baade and F. Zwicky, Phys. Rev. **45**, 138 (1934) and **46**, 76 (1934). Proc. Nat. Acad. Sci. **20**, 259 (1934). See also F. J. M. Stratton, *Handbuch der Astrophysik*, Vol. 7 (1936), p. 671.
[2] F. Zwicky, The Scientific Monthly **40**, 461 (1935).

35. The Diurnal Variation of Atmospheric Condensation Nuclei. N. E. BRADBURY AND H. J. MEURON, *Stanford University.*—Continuous records of the diurnal variation of the density of atmospheric condensation nuclei have been obtained over a period of four months. The apparatus employed consists of a Wilson cloud chamber with an expansion ratio of 1.15. At regular intervals the air in the chamber is replaced by a fresh sample, saturated with water vapor, and subjected to an expansion. A beam of light passing through the chamber is diminished in intensity by the resulting fog, and the degree of extinction may be related to the nuclei density. The diurnal variation in nuclei density shows a definite forenoon and evening maximum with a pronounced minimum prior to sunrise and a mid-day minimum of lesser extent. Such a variation might be expected in the normal daily convective cycle. The average hourly values of nuclei density have been compared with the hourly averages of the local component of the diurnal variation of the earth's electric field for this station. The results indicate that in a large measure, if not entirely, the variations in the local component of the earth's potential gradient arise out of variations in the nuclei density.

36. A New Radiation Pyrometer for the Measurement of Low and High Temperatures. JOHN STRONG, *Astrophysical Observatory, California Institute of Technology.*—An instrument will be described which uses a thermopile to measure energy emitted at various wave-lengths in the spectral region between 6 and 35μ. The various monochromatic bands employed are obtained by successive reflections from crystal surfaces. The instrument may be used to measure the surface temperature of cold or hot solids. Also, it may be used to measure the temperature of gases, vapors and liquids, including clouds. The atmosphere is particularly transparent for the residual rays of quartz (8.9μ) and carborundum (12μ). Accordingly, these wave-lengths are useful for observation of temperatures where a long air path is involved. A resume of astronomical and meteorological observations will be given.

37. The Mechanism of the Positive and Negative Point Coronas in Air at Atmospheric Pressure. GERVAIS W. TRICHEL, *University of California* (*Introduced by Leonard B. Loeb*).—The current fluctuations in positive and negative point to plane corona have been studied by coupling a radio receiver and oscillograph to the corona circuit. Negative points supply sufficient electrons by secondary processes at the point. The ionization by electron avalanches builds a space charge which in $\sim10^{-8}$ sec. chokes off the discharge. As the region is cleared of positive ions the current falls exponentially until the fields are restored to the firing value. The discharge frequency is regular, increases with applied potential, and is proportional to the current. The positive point corona consists of positive space charge streamers emerging from the whole point composed of electron avalanches propagated outward by photo-ionization in the gas. The diffusion of positive space charge eventually extinguishes the streamer and the arrival of a *negative ion* is required to start a new streamer. To do this, $X/p>90$ near the point to ionize the ion. The frequency of the streamer bursts for a fine point is from 3×10^5 to 2×10^6 per second. The mechanism of spark breakdown in positive point corona may be explained on this basis.

SUPPLEMENTARY PROGRAM

38. The Mechanism of the Positive Ion Emission from Catalysts. ALLEN V. HERSHEY, *University of California* (*Introduced by Leonard B. Loeb*).—It has been possible to draw some definite conclusions concerning the mechanism of the emission of positive ions from Kunsman catalysts as a result of experiences gained in a search for a pure source of ions. The catalysts are known to contain Fe, and a few percent each of Al_2O_3 and an alkali oxide, for example, K_2O. Since the potassium is present in chemical combination with oxygen, it cannot be emitted as an ion without either the emission of O_2 or the removal of oxygen by some reducing agent. The iron effectively furnishes this reducing agent, and FeO is probably the product formed in accordance with the reaction

$$Fe+K_2O\rightarrow FeO+2K^++2e^-.$$

The metallic iron also facilitates the escape of the liberated electrons. The accumulation of FeO around the crystals of K_2O tends to block the emission of ions by preventing the passage of oxygen from the K_2O to the more distant Fe, and by obstructing the electrons. Variation in the emission under various conditions from an impure catalyst containing both sodium and potassium could be interpreted in terms of the inhibitory effect of the FeO.

Author Index to Abstracts

Alvarez, Luis—No. 1

Ballard, Stanley S.—No. 5
Batdorf, Samuel B. and Erich W. Beth—No. 9
Bath, Jean—see Ellis, Joseph W.
Beth, Erich W.—see Batdorf, Samuel B.
Bollman, V. L. and Jesse W. M. DuMond—No. 18
Bradbury, N. E. and H. J. Meuron—No. 35
Brode, B. and Dale R. Corson—No. 16

Cohn, Willi M.—No. 32
Corson, Dale R.—see Brode, B.

Dember, A.—see Gould, W. O.
——, A. Goetz and W. O. Gould—No. 25
Drill, H. T.—No. 27
DuMond, Jesse W. M.—see Bollman, V. L.

Ehrenkranz, Florence—No. 20
Ellis, Joseph W. and Jean Bath—No. 6

Fine, Paul—No. 23
Fleming, G. and J. E. Henderson—No. 30
Fricke, E.—see Knudsen, V. O.

Goetz, A.—see Dember, A.
——see Gould, W. O.
—— and S. Scott Goetz—No. 4
Goetz, S. Scott—see Goetz, A.
Gould, W. O.—see Dember, A.
——, A. Goetz and A. Dember—No. 26
Grahame, D. C. and G. T. Seaborg—No. 28

Hale, Donald H.—No. 31
Henderson, J. E.—see Fleming, G.
——see Rubens, S. M.
—— and S. M. Rubens—No. 14
Hershey, Allen V.—No. 11; No. 38
Hirsh, F. R., Jr.—No. 17
Houston, W. V.—No. 12

Jordan, W. H.—No. 3

Kaplan, Joseph—No. 33
Knudsen, V. O. and E. Fricke—No 13
Kyropoulos, S.—No. 29

Langer, R. M.—No. 10
Livingood, J. J. and G. T. Seaborg—No. 22
Loughridge, Donald—see Trueblood, Harold
—— and N. Kermit Olsen—No. 19

Meuron, H. J.—see Bradbury, N. E.

Olsen, N. Kermit—see Loughridge, Donald H.

Rubens, S. M.—see Henderson, J. E.
—— and J. E. Henderson—No. 15

Schiff, L. I.—No. 2
Seaborg, G. T.—see Grahame, D. C.
—— see Livingood, J. J.
Staub, H.—see Stephens, W. E.
—— and W. E. Stephens—No. 7
Stephens, W. E.—see Staub, H.
—— and H. Staub—No. 8
Strong, John—No. 36

Trichel, Gervais W.—No. 37
Trueblood, Harold and Donald Loughridge—No. 21

Wilson, Robert—No. 24

Zwicky, F.—No. 34